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CASE STUDY OF BULLWHIP EFFECT IN SUPPLY CHAINS

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ABSTRACT
Supply chains are dynamic systems. Overall supply chain evaluation needs to include the Bullwhip Effect (or Whiplash Effect). The Bullwhip Effect shows how small changes at the demand end of a supply chain are progressively amplified for operations further back in the chain, resulting in increased cost and poorer service. It is understood that demand forecast variance contributes to that effect in the chain. With this understanding, the authors experimented with two cases: i) stable demand with a single 5 % change in demand, and ii) changing demand in periodic 10 % increases and later in the same decreases. Increasing variability of orders and inventories up the supply chain is evident. The effect indicates a lack of synchronization among supply chain members because of corrupt key information about actual demand. When we understand the nature of supply chain dynamics, there are several actions concerned with coordinating the activities of the operations in the chain, which is discussed in the last part of the paper. By combining the right planning concepts with new real-time capabilities, planners are able to make more accurate decisions with greater flexibility.
Keywords: supply chain, bullwhip effect, production rate variability

1. INTRODUCTION
Supply chain management is a hot and very popular topic in business today. Many companies are achieving significant competitive advantage by the way they configure and manage their supply chain operations. The idea is to apply a total systems approach to managing the entire flow of information, materials, and services from raw materials suppliers through factories and warehouses to the end customer [1]. A supply chain, logistics network, or supply network is a coordinated system of organizations, people, activities, information and resources involved in moving a product or service in physical or virtual manner from supplier to customer. Supply chains link value chains [2].
Today, the ever increasing technical complexity of standard consumer goods, combined with the ever increasing size and depth of the global market has meant that the link between consumer and vendor is usually only the final link in a long and complex chain or network of exchanges.
Although many companies and corporations today are of importance not just on national but also on global scale, none are of a size that enables them to control the entire supply chain, since no existing company controls every link from raw material extraction to consumer.

2. BULLWHIP EFFECT
The Bullwhip Effect (or *Whiplash Effect*) is an observed phenomenon in forecast-driven distribution channels. The effect indicates a lack of synchronization among supply chain members. Even a slight change in customer sales ripples backward in the form of amplified oscillations upstream, resembling the result of a flick of a bullwhip handle. Because the supply patterns do not match the demand patterns, inventory accumulates at various stages.
The concept has its roots in Forrester's *Industrial Dynamics* [3]. Because customer demand is rarely perfectly stable, businesses must forecast demand in order to properly position inventory and other resources. Variability coupled with time delays in the transmission of information up the supply chain and time delays in manufacturing and shipping goods down the supply chain create the Bullwhip Effect.

Forecasts are based on statistics, and they are rarely perfectly accurate. Because forecast errors are a given, companies often carry an inventory buffer called "safety stock". Moving up the supply chain from end-consumer to raw materials supplier, each supply chain participant has greater observed variation in demand and thus greater need for safety stock. In periods of rising demand, down-stream participants will increase their orders. In periods of falling demand, orders will fall or stop in order to reduce inventory. The effect is that variations are amplified as one moves upstream in the supply chain (further from the customer). Bullwhip Effect is also attributed to the separate ownership of different stages of the supply chain. Each stage in such a structured supply chain tries to amplify the profit of the respective stages, thereby decreasing the overall profitability of the supply chain [4,5,6,7].
Factors contributing to the Bullwhip Effect: forecast errors, overreaction to backlogs, lead time (of information – orders and of material) variability, no communication and no coordination up and down the supply chain, delay times for information and material flow, batch ordering (larger orders result in more variance), rationing and shortage gaming, price fluctuations, product promotions, free return policies, inflated orders.

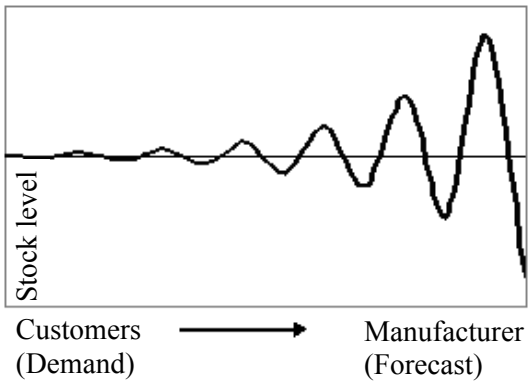

Figure 1. Stock variability amplification in a supply chain due to Bullwhip Effect.

The main cause is a perfectly understandable and rational desire by the different links in the supply chain to manage their production rates and stock levels sensibly [8]. To demonstrate this, two special cases with comments are following.

2.1. Case 1: Stable demand with a single 5 % change in demand

We present a four-stage supply chain where a manufacturer is served by three tiers of suppliers (see Table 1). The market demand has been running at a rate of 100 items per period, but in period 2 demand reduces to 95 items per period. All stages in the chain work on the principle that they will keep in stock one period's demand.

Table 1. Changes of production rates and stock levels along supply chain (single 5 % leap).

Period	Demand (market)	Manufacturer		Supplier 1		Supplier 2		Supplier 3	
		Prod. rate	Stock	Prod. rate	Stock	Prod. rate	Stock	Prod. rate	Stock
1	100	100	100 100	100	100 100	100	100 100	100	100 100
2	95	90	100 95	80	100 90	60	100 80	20	100 60
3	95	95	95 95	100	90 95	120	80 100	180	60 120
4	95	95	95 95	95	95 95	90	100 95	60	120 90
5	95	95	95 95	95	95 95	95	95 95	100	90 95
6	95	95	95 95	95	95 95	95	95 95	95	95 95

The column headed 'Stock' for each level of supply shows the starting stock at the beginning of the period and the finish stock at the end of the period. At the beginning of period 2, the manufacturer (*M*) has 100 units in stock (that being the rate of demand up to period 2). Demand in period 2 is 95 and so the *M* knows that it would need to produce sufficient items to finish up at the end of the period with 95 in stock (this being the new demand rate). To do this, it need only manufacture 90 items; these, together with 5 items taken out of the starting stock, will supply demand and leave a finished stock of 95 items. The beginning of period 3 finds the *M* with 95 items in stock. Demand is also 95 items and therefore its production rate to maintain a stock level of 95 will be 95 items per period. The manufacturer now operates at a steady rate of producing 95 items per period. We should note that a change in demand of only 5 % has produced a fluctuation of 10 % in the *M*'s production rate.
The same logic is used through to the first-tier supplier (*S1*). At the beginning of period 2, the *S1* has 100 items in stock. The demand which it has to supply in period 2 is derived from the production rate of the *M*. This has dropped down to 90 in period 2. The *S1* therefore has to produce sufficient to supply the demand of 90 items and leave one period's demand (now 90 items) as its finish stock. A production rate of 80 items per period will achieve this. It will therefore start period 3 with an opening stock of 90 items, but the demand from the *M* has now risen to 95 items. It therefore has to produce sufficient to fulfil this demand of 95 items and leave 95 items in stock. To do this, it must produce 100 items in period 3. After period 3 the *S1* then resumes a steady state, producing 95 items per period. The fluctuation has been even greater than that in the *M*'s production rate, decreasing to 80 items a period, increasing to 100 items a period, and then achieving a steady rate of 95 items a period.
This logic can be extended right back to the third-tier supplier (*S3*). After period 5 the *S3* resumes a steady state, producing 95 items per period. The fluctuation of production rate has been the most drastic, decreasing to 20 items a period, increasing to 180 items a period. In this simple case, the decision of how much to produce each period was governed by the following relationship:

$$\text{Production rate} = 2 \times \text{demand} - \text{starting stock} \quad (\geq 0) \qquad \ldots (1)$$

Shown case does not include any time lag between a demand occurring in one part of the supply chain and it being transmitted to its supplier. In practice there will be such a lag!

2.2. Case 2: Changing demand in periodic 10 % increases and later in 10 % decreases

Table 2 presents a two-stage supply chain for an item with sales growing at 10 % per period for 5 periods and then shrinking by 10 % for 5 more periods. Both stages in the chain work on the principle that they will keep in stock two period's demand. Orders and deliveries are made in the same period.

$$\text{Production rate} = 3 \times \text{demand} - \text{starting stock} \quad (\geq 0) \qquad \ldots (2)$$

Table 2. Changes of production rates and stock levels (continual 10 % demand changes).

Period	Demand (market)	Manufacturer		Supplier	
		Production rate	Stock start / finish	Production rate	Stock start / finish
1	50	50	100 / 100	50	100 / 100
2	55	65	100 / 110	95	100 / 130
3	61	73	110 / 122	89	130 / 146
4	67	79	122 / 134	91	146 / 158
5	74	88	134 / 148	106	158 / 176
6	67	53	148 / 134	0 (-17)	176 / 123
7	60	46	134 / 120	15	123 / 92
8	54	42	120 / 108	34	92 / 84
9	49	39	108 / 98	39	84 / 78
10	44	34	98 / 88	24	78 / 68

For example, in period 2 the sales of 55 units result in ending stock of 45, which is thereafter corrected by an order and delivery of 65 units to bring the period 3 beginning stock to its desired level

of 110. Table 2 clearly shows the Bullwhip Effect. The sales go up 48 % (50 to 74), and thereafter go down 41 % (74 to 44). Orders to the manufacturer go up by 76 % (50 to 88), and then down by 61 % (88 to 34). Even more dramatically, orders to the supplier go up by 112 % (50 to 106) and then down by 100 % (106 to 0). It is important to note that besides stock effects, similar problems would be extant in manufacturing capacity requirements, response times, and obsolescence [9].
Both cases are very real. We have seen examples where suppliers have been shut down completely for many weeks when the orders at the end of the supply chain are reduced only slightly!

3. COUNTERMEASURES TO THE BULLWHIP EFFECT

The key question becomes: How can the Bullwhip Effect be ameliorated? Companies must understand fully its main causes and implement some new strategies. Different actions are possible:

- Minimize the cycle time in receiving projected and actual demand information.
- Establish the monitoring of actual demand for product to as near a real time basis as possible.
- Understand product demand patterns at each stage of the supply chain.
- Increase the frequency and quality of collaboration through shared demand information.
- Minimize or eliminate information queues that create information flow delays.
- Eliminate inventory replenishment methods that launch demand lumps into the supply chain.
- Reduce the order sizes and implement capacity reservations.
- Eliminate incentives for customers that directly cause demand accumulation and order staging prior to a replenishment request, such as volume transportation discounts.
- Minimize incentive promotions that will cause customers to delay orders and thereby interrupt smoother ordering patterns.
- Offer your products at consistently good prices to minimize buying surges brought on by temporary promotional discounts.
- Identify, and preferably, eliminate the cause of customer order reductions or cancellations.
- Implement special purchase contracts in order to specify ordering at regular intervals, limit free return policies.

4. CONCLUSION

The Bullwhip Effect is a wasteful phenomenon that occurs due to a lack of information across the supply chain. Basically, the Bullwhip Effect is safety stock for safety stock; because suppliers hold extra stock for their customers the same way retailers hold extra stock for their customers. Suppliers need safety stock, for the safety stock.
The negative effect on business performance is often found in excess stocks, quality problems, higher raw material costs, overtime expenses and shipping costs. In the worst-case scenario, customer service goes down, lead times lengthen, sales are lost, costs go up and capacity is adjusted. An important element to operating a smooth flowing supply chain is to mitigate and preferably eliminate the Bullwhip Effect.

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